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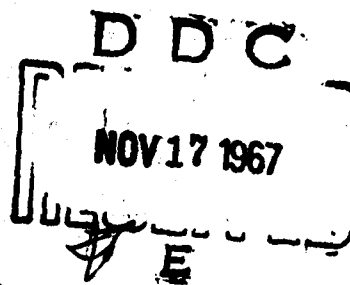N. Z. Ariel', L. A. Klíuchnikova

WIND OVER A CITY

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WIND OVER A CITY

by

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In this work are analyzed observational wind speed data from television towers in Kiev and Leningrad.

The diurnal course of mean vertical wind speed profiles, up to a height of 180 m is presented. The roughness length and the angle of the change in wind direction with height, over a city, is obtained.

Wind speed, the deviation of its direction from the ~~deviation~~ *direction* of the isobar, and the diurnal variation of the wind speed in the boundary layer of the atmosphere are determined to a great extent by the stratification of the atmosphere and the character of the underlying surface.

The wind profile over a level surface with low vegetative cover, i.e., with small roughness lengths, at the present time, has been relatively well investigated. Under complex relief conditions (cities and forested areas) the wind profile may have its own characteristics since, under such circumstances, the roughness differs to a great extent from the roughness of a level surface.

In the construction of buildings, towers, electric communication lines and etc., it is necessary to know the character of the distribution of wind speed with height over a city. In recent years a direct measurement of wind speed at greater heights became possible owing to the extensive construction of television antenna towers.

In this work are presented certain wind characteristics over a city, which are obtained on the basis of the analysis of experimental data. The data on wind speed observations made on television towers in Kiev and Leningrad are used.

In Kiev, observations were made at four heights (24, 48, 96 and 180 m) with strengthened contact anemometers of the CGO (Central Geophysical Observatory) design. Double theodolite pilot-balloon observations were made simultaneously with the (television tower) observations at Kiev. A disintegrated pressure field with weak wind speeds and the passage of secondary fronts was characteristic of the observational periods (from 13 August through 3 September 1957).

In Leningrad the observations were taken at eight heights (18, 35, 50, 66, 82, 98, 110 and 146 m), with ordinary contact anemometers. Considerable cloudiness, at times accompanied with fogs or light precipitation was characteristic for the observation period from 4 through 25 November 1957.

Both in Kiev and Leningrad the television antenna towers were placed in the center of the city in the midst of tall buildings.

A total of 26 twenty-four hour series were used in this work (11 for Kiev and 15 for Leningrad). The mean hourly wind speeds were determined for Kiev every other hour during the series, and for Leningrad - every hour.

. The roughness of the underlying surface z_{00} was determined according to the wind profile over a city under equilibrium conditions ($\epsilon = 0$). Data of the wind speeds on television towers were used. The mean value of z_{00} was found to be 4.6 m for Kiev and 4.4 m for Leningrad.

The roughness of the underlying surface, under conditions different from the equilibrium, z_0 , was calculated according to the data obtained from Kiev by the formula

$$z_0 = z_1 (1 - c_1 \epsilon \cot\alpha)^{\frac{1}{\epsilon}} ,$$

where z_1 - is the height of the lower anemometer, c_1 - is wind speed at height z_1, α — is the inclination of a straight line to the coordinates.

The dependence of z_0 on stratification is presented in Fig. 1. The curve I gives the relationship between $\frac{z_0}{z_{00}}$ and ϵ for the city, the curve II - for a level surface (after Ogneva). From a comparison between curves I and II it may be seen that with a large roughness length of z_{00} the relationship between z_0 and ϵ is significantly less than with small z_{00} values. If for a level surface (according to Ogneva) with a change of ϵ value from +0.3 to -0.5, the value of $\frac{z_0}{z_{00}}$ changes from 0.1 to 4.6 ($\approx$ 50 times) then for a city $\frac{z_0}{z_{00}}$ changes from 0.6 to 1.8 (3 times).

In Fig. 2 are presented mean wind speed profiles for Kiev constructed on semi-logarithmic coordinates. These clearly reflect the influence of stratification on wind distribution with height: during the night hours the profiles correspond to a stable state of the atmosphere, during the day - to unstable. Evidently, the power law for the changes of wind with height over a city is observed up to heights 100-150 m.

It is interesting to note that during morning hours a break in the profile is noted at 96m: in the lower layer the wind profile corresponds to an isothermal state (8-9 hr) or to an unstable state (10-11 hr), but above 96 m - to an inversion.

Often for calculating the wind speed in the lower layers on the basis of wind speeds aloft and conversely, the ratio $\frac{c_z}{v_g}$ is used, where c_z - is the wind speed at a certain height, v_g - geostrophic wind speed.

In the present work the ratio $\frac{c_z}{v_g}$, for various states of the atmosphere, was examined.

Fig. 1

Fig. 2

All occurrences when $\varepsilon < -0.1$ were classified as an unstable state, as neutral $0.1 < \varepsilon < -0.1$, as a stable state $\varepsilon > 0.1$. For Leningrad ε was not calculated, therefore the selection of data for different states of the atmosphere was made on the basis of the wind profile. The geostrophic wind was calculated on the synoptic charts by means of a gradient circle.

Table 1

Value of $\dfrac{c_z}{v_g}$

Station	Height m	Unstable State		Neutral State		Stable State	
		$\dfrac{c_z}{v_k}$	No. of occ.	$\dfrac{c_z}{v_k}$	No. of occ.	$\dfrac{c_z}{v_k}$	No. of occ.
Kiev	20	0.5?	9	0.40	5	0.55	7
Leningrad	20	0.35	(8)	0.33	17	0.33	16
	40	0.50	8	0.49	18	0.54	16
	98	0.61	8	0.64	17	0.69	15
	150	0.71	7	0.70	16	0.90	17

Results of calculations presented in Table 1, show that the relationship between $\dfrac{c_z}{v_k}$ and the stratification is expressed very weakly, especially in the lower layer. However, at a height of ~50m there occurs a change in the sign of this relationship. Below 50 m, $\dfrac{c_z}{v_r}$ is larger during an unstable state, above 50 m - greater during a stable state.

For Kiev, v_g has been calculated for a disintigrating pressure field. The wind speeds were small and the number of occurrences on an average were very few. Therefore, the values $\dfrac{c_z}{v_g}$ are less reliable for Kiev than for Leningrad.

The slight influence of stratification on the ratio $\dfrac{c_z}{v_k}$, obviously, may be explained by the fact that under city conditions, where the height of the buildings is of an order of 20 m or higher, the underlying surface has a greater influence on the wind than the stratification.

An analysis of the pilot-balloon observations made it possible to make a certain preliminary evaluation of the magnitude of the angular change in wind direction with height and its relationship with ε. Occurrences of frontal passages and advection were not taken into consideration.

In Fig. 3, the angle δ is given for the layers 0-500, 0-1000 and 0-2000 m and its relationship with ε. δ - is the angle between the wind direction at the earth's surface and its direction in the upper boundary of the layer.

According to Pavlovsk data, where the roughness length evidently is less than that for Kiev and Leningrad, the size of the angle is $\delta \approx 20°$.

According to our calculations the angle could be over 40° for Kiev. The size of the angle increases with the increase in stability, during which

$\frac{d\theta}{dz}$ increases with an increase in the thickness of the layer, in which

the angle is measured, i.e., the influence of stratification on the magnitude of the angular change in wind direction with height is felt up to great heights (2000 m).

The problem on the diurnal variation of wind over a city is also of interest. The diurnal variation of wind at different heights was constructed according to averaged data (for Leningrad for 15 days, for Kiev - 11 days) (Fig. 4).
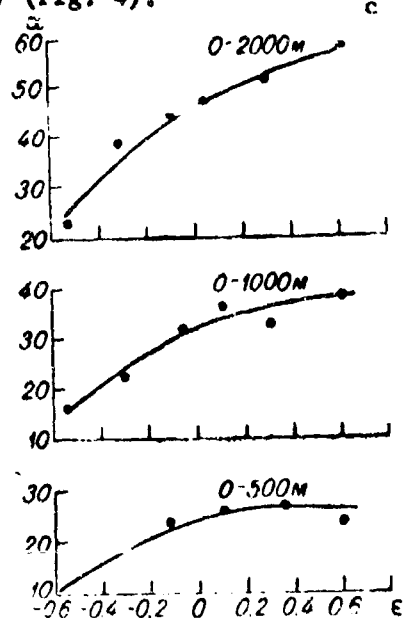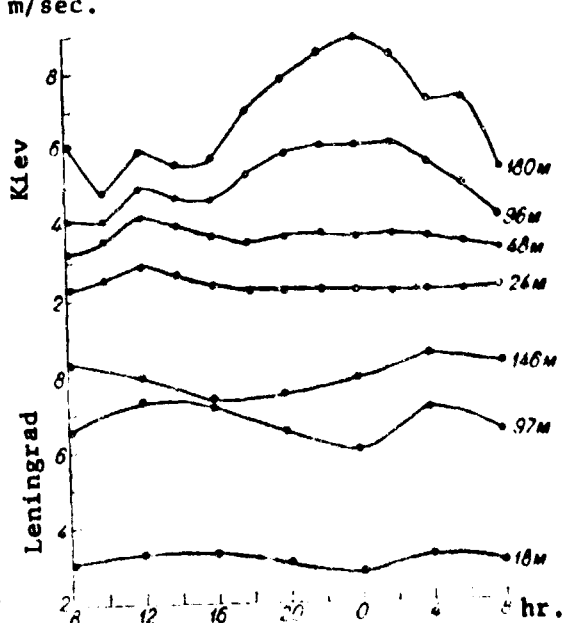

Fig. 3   Fig. 4

The diurnal variation of wind for both Kiev and Leningrad, is expressed weakly at the 20-25 m height, which is comparable to the height of buildings, however, a small maximum is observed during the day and a minimum at night (the amplitude of the wind speed $\sim$ 0.7 m/sec).

The height at which diurnal variation changes to the reverse is found somewhere between 50-80 m for Kiev and between 100-150 m for Leningrad.

It is interesting to note that in the recently published work of a Japanese specialist M. Tohaha [2], data on the diurnal variation of wind speed over a flat terrain (rice field) are presented. The height at which the reversal of the diurnal variation of wind speed takes place is less than 90 m.

Thus, it may be noted that over cities the large roughness length of the underlying surface causes a weakening of the stratification's influence on wind speed in the lower layers.

The deviation angle of the surface wind from the isobars increases over the city.

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